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Patenttihakemuksen numero ja luokka on mainittava kirjelmässä PRH:lle

Suoritetussa uutuustutkimuksessa, jossa on huomioitu saatavilla ollut tutkimusraportti vastaavasta WO-hakemuksesta 01/11790 A1 (H04B 1/10), ei ole ilmennyt esteitä hakemuksen hyväksymiselle (PL 2 §). Hakijaa pyydetäänkin toimittamaan patenttivaatimukset myös ruotsin kielellä.

Tekniikan tasoa edustaa patenttijulkaisu WO 00/48354 A1 (H04L 7/04), jossa mm. vastaanotetusta signaalista lasketaan korrelaatio vertailusignaalin kanssa, päättyen lopulta optimaaliseen tahdistuskohtaan vastaanotetulle signaalille --- esim. tiivistelmä; vaatimus 1.

Toinen tekniikan tason julkaisu WO 01/03397 A1 (H04L 27/00) käsittelee tahdistusta ja modulaatiotyyppin tunnistusta vastaanotetusta signaalista --- esim. tiivistelmä; vaatimukset 1-11.

Molemmat mainitut viitejulkaisut ovat tulleet julkisiksi käsiteltävän hakemuksen tekemispäivän jälkeen, mutta niiden etuoikeuspäivät ovat aikaisempia kuin ko. tekemispäivä.



Tutkijainsinööri
Puhelin: puh. (09) 6939 5762

Mikko Flykt

Liitteenä tutkimusraportti ja viitejulkaisut.

Lausumanne huomautusten johdosta on annettava viimeistään yllämainittuna määräpäivänä. Jollette ole antanut lausumanne virastoon viimeistään mainittuna määräpäivänä tai ryhtynyt toimenpiteisiin tässä välipäätöksessä esitettyjen puutteellisuuksien korjaamiseksi, jätetään hakemus sillensä (patenttilain 15 §). Sillensä jätetty hakemus otetaan uudelleen käsiteltäväksi, jos Te neljän kuukauden kuluessa määräpäivästä annatte lausumanne tai ryhdytte toimenpiteisiin esitettyjen puutteellisuuksien korjaamiseksi ja samassa ajassa suoritate vahvistetun uudelleenkäsittelymaksun. Jos lausumanne on annettu virastoon oikeassa ajassa, mutta esitettyjä puutteellisuuksia ei ole siten korjattu, että hakemus voitaisiin hyväksyä, se hylätään, mikäli virastolla ei ole aihetta antaa Teille uutta välipäätöstä (patenttilain 16 §). Uusi keksinnön selitys, siihen tehdyt lisäykset ja uudet patenttivaatimukset on aina jätettävä kahtena kappaleena ja tällöin on otettava huomioon patenttiasetuksen 19 §.

Maksu perustuu kauppa- ja teollisuusministeriön antamaan asetukseen 1027/2001 Patentti- ja rekisterihallituksen maksullisista suoritteista muutoksineen.

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19991696	H04B 1/10, H04L 27/00

TUTKITTU AINEISTO
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VIITEJULKAISUT		
Kategoria*)	Julkaisun tunnistetiedot	Koskee vaatimuksia
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021 1022 1023 1024 1025 1026 1027 1028 1029 1030 1031 1032 1033 1034 1035 1036 1037 1038 1039 1040 1

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Block diagram of a digital communication receiver system. The system includes a Buffer (100), Derotators (105), Synchronization (115), Derotation (125), Channel estimation (135), Equalizer (145), and a Decoding Unit (150). The input is y_n , which goes to the Buffer and Derotation. The Buffer outputs y_n to the Derotators. The Derotators output y_n^1 to the Derotation block. The Derotation block outputs (\bar{y}_n^V) to the Equalizer. The Equalizer outputs (u_n^V) to the Decoding Unit. The Decoding Unit outputs u_n^{dec} . The Synchronization block (115) receives y_n and outputs a TS signal. The Channel estimation block (135) receives y_n and outputs $(\hat{h}_l^w)_{l=(0,L)}$ and $(\hat{h}_l^w)_{l=(0,L)}$.

(57) **Abstract:** In a communication system, including a transmitter and a receiver, the receiver is synchronized with the transmitter, and a modulation type in a signal transmitted by the transmitter and received by the receiver is detected. A first portion of the received signal is correlated with one or more signals, representing modulation types used by the communication system to detect the type of modulation being used. Synchronization is established between the transmitter and the receiver. The first portion may be correlated with each of one or more different signals, representing various modulation types used in the communication system to detect the type of modulation used. Alternately, the first portion of the received signal may be derotated by different amounts, to produce a plurality of derotated signals that are correlated with the signal representing modulation used by the communication system, in order to detect the type of modulation used. If the correlation does not result in a determination of the modulation type, either a predetermined modulation type is selected or the decision of modulations type is made at a later stage, based, e.g., on a comparison of signal qualities or equalization results.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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SYNCHRONIZATION AND DETECTION OF MODULATION TYPE

BACKGROUND

5 This invention relates generally to methods and apparatuses for synchronization and modulation type detection. More particularly, this invention relates to methods and apparatuses for synchronization and modulation type detection in a communication system.

10 In some cellular communication systems, it can be advantageous to use different modulation types for exchanging information, e.g., between transmitter such as a base station and a receiver such as a mobile station or a fixed cellular terminal. For instance, some modulation types may perform well against interference and background noise at high velocities of the mobile station. This kind of modulation type is normally associated with a low data rate. Other modulation types may provide higher data rates but may be
15 more sensitive to noise, etc. Such modulation types are only suitable at low velocities of the mobile station and in limited areas where the noise is small compared to the received signal strength, e.g., offices or cities.

One example of a cellular system using different modulation types is the proposed EDGE (Enhanced Data Rates for Global System for Mobile Communication (GSM)
20 Evolution) system in which GMSK (the modulation type used in GSM systems today) will be used as the robust low data rate modulation and offset 8-PSK will be used as the modulation for higher data rates.

In communication systems such as these, information is typically exchanged in bursts of a fixed length. Typically, the modulation type is the same within a burst. Using
25 different modulation types in the same digital communication system requires detection of the modulation type used in a particular burst. One simple way to determine the modulation type is to use some kind of signaling between the transmitter and the receiver to indicate which modulation type is being used. However, this signaling decreases the information data rate and may therefore not be desirable. To avoid the need for this
30 signaling, blind modulation detection may be used, requiring detection of the transmitted

C O N F I R M A T I O N C O P Y

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bits and the modulation type in the receiver. The complexity of the modulation detection device should be kept low in order to minimize the processing power required in the receiver. Additionally, the detection should be adapted to the received signal quality for a good trade-off between complexity and performance.

5 Various attempts have been made to detect modulation types. For example, U.S. Patent No. 5,600,673 to Kimura et al. describes the use of phase differences between a recovered data clock and received data for discriminating modulation formats. U.S. Patent No. 4,933,958 to Brandl et al. describes a similar technique for modulation detection. Neither of these patents addresses the problem of Inter Symbol Interference
10 (ISI) which is common in present radio communication systems, due to multipath propagation of radio waves.

 In cellular radio communication systems, it is important that the receiver be synchronized to the transmitter, i.e., the local time reference of the receiver should be synchronized to the time reference of the transmitter. For this purpose, synchronization
15 signals are transmitted periodically by the transmitter. The receiver synchronizes itself with the transmitter, using the synchronization signals.

 Therefore, there is a need for an efficient modulation detection technique that, in a simple and reliable way, detects the type of modulation used. Further, the detection unit should be reliable even under severe Inter Symbol Interference (ISI) conditions. To
20 reduce the complexity of the receiver and thus minimize processing power, modulation type detection should be done as soon as possible after receipt of the signal, e.g., at the same time as synchronization.

SUMMARY

25 It is therefore an object of the invention to provide a simple and efficient way for detecting a type of modulation in a received signal. It is a further object of the invention to provide a modulation detection technique that is effective under severe interference conditions. It is yet a further object of the invention to provide a technique for

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performing or at least attempting modulation type detection simultaneously with synchronization.

According to exemplary embodiments, this and other objects are met by methods and apparatuses for synchronization and modulation detection in a communication system including a transmitter and a receiver. The receiver is synchronized with the transmitter, and a modulation type in a signal transmitted by the transmitter and received by the receiver is detected or an attempt is made to detect the modulation type. A first portion of the received signal is correlated with one or more signals representing modulation types used by the communication system to detect the type of modulation being used in the received signal. Synchronization between the transmitter and the receiver is established.

According to a first embodiment, the first portion of the received signal is correlated with each of one or more different signals representing various modulation types used in the communication system to detect the type of modulation used. According to a second embodiment, the first portion of the received signal is derotated by different amounts to produce a plurality of derotated signals that are correlated with a signal representing the modulation type used by the communication system in order to detect the type of modulation used. According to a third embodiment, if the modulation type is not detected by correlating the first portion of the received signal with each of one or more different signals representing the various modulation types, either a predetermined modulation type is determined to be the modulation type, or the modulation type is decided based, e.g., on a comparison of signal qualities or equalization results. According to a fourth embodiment, if the modulation type is not detected by correlating the derotated signals with a signal representing the modulation used by the communication system, either a predetermined modulation type is determined to be the modulation type, or the modulation type is decided based, e.g., on a comparison of signal qualities or equalization results.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of this invention will become apparent by reading this description in conjunction with the accompanying drawings, in which like reference numerals refer to like elements and in which:

FIGS. 1A-1D illustrate apparatuses for synchronization and modulation type detection according to exemplary embodiments; and

FIGS. 2A-2D illustrate methods for synchronization and modulation type detection according to exemplary embodiments.

10 DETAILED DESCRIPTION

For illustrative purposes, the following description is directed to a cellular radio communication system, but it will be understood that this invention is not so limited and applies to other types of communication systems.

FIG. 1A illustrates a simultaneous synchronization and modulation type detection apparatus according to a first embodiment. This system may be included in a receiver such as a mobile station or a fixed cellular terminal. As shown in FIG. 1A, a received signal y_n that has been down converted from a radio signal to a baseband signal and sampled at some rate, e.g., the symbol rate, with a predefined burst length is stored in a Buffer 100. The signal includes a first portion containing a known symbol pattern, e.g., a training sequence, and a second portion containing, e.g., data and/or control and signalling information. The first portion of the received signal y_n within the burst, e.g., a training sequence, is output from the Buffer 100 to a Synchronization unit 110. A correlation between the different training sequences for each of the M possible modulation types used in the particular communication system, TS_1, \dots, TS_m , and the received training sequence is performed in the Synchronization unit 110 to detect the type of modulation used in the received signal and to determine where the training sequence starts within the burst to establish burst synchronization. Mathematically, this can be explained in the following way.

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Assume a burst of the received signal, down converted to baseband and sampled, can be written as:

$$y_n = h_0 u_n + \dots + h_L u_{n-L} + e_n, \quad n = 1, \dots, K \quad (1)$$

- 5 where K is the burst length, $H = [h_0 \dots h_L]$ is the radio channel, u_k is the transmitted symbol at time k , and e_n is some kind of noise. The correlation in the Synchronization unit 110 is done by computing:

$$c^i(k) = \frac{1}{n_{TS}^i} \sum_{n=1}^{n_{TS}^i} y(n+k) u_{TS}^i(n), \quad k = n_0, \dots, n_0 + N, \quad i = 1, \dots, M \quad (2)$$

- where $c^i(k)$ is the k -lag cross-correlation between the received signal and $u_{TS}^i(n)$, which is the known training sequence for modulation type i , N is the synchronization window size, and M is the total number of possible modulation types used in the communication system. Since the radio channel is assumed to be of order L , the starting or synchronization position and modulation type can be chosen using the following equations:

$$15 \quad \text{Energy}^i(k) = \sum_{n=k}^{k+L} |c^i(k)|^2, \quad i = 1, \dots, M \quad (3)$$

$$\text{Sync. Pos, Modulation Type} = \max_{k \in [0, N]} \max_{i \in [1, M]} |\text{Energy}^i(k)|^2 \quad (4)$$

- As can be seen from these equations, the synchronization position and modulation type that result in the largest energy correlation $\text{Energy}^i(k)$ are determined to be the correct modulation type and synchronization position. If $M = 1$, this means only one type of modulation is being used. This is described, for example, in J. Proakis, Digital Communications. McGraw-Hill Inc., New York, 1995, and WO 96/13910.

- Information representing the detected modulation type is fed to a Derotation unit 120 that rotates the second portion of the received signal, e.g., an information sequence, based on the detected modulation type. The rotation is performed in order to compensate

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for possible offsets introduced in the transmitter. For instance, assume that $M = 2$, and the two modulation types that are used are either $\pi/8$ offset 8-PSK, so that the transmitted signal u , is given as:

$$u_t = e^{j\frac{\pi}{8}} v_t \quad (5)$$

$$\text{where } v_t \in e^{j\frac{\pi}{4}k_t}, k_t \in (0, \dots, 7) \quad (6)$$

or GMSK, i.e., the linear approximation, in which case the transmitted signal u , is given as:

$$u_t = e^{j\frac{\pi}{2}} v_t \quad (7)$$

$$\text{where } v_t \in (-1, 1). \quad (8)$$

In order to compensate for the offset, the received signal is derotated by $e^{-j\frac{\pi}{8}}$ in the 8-PSK case and $e^{-j\frac{\pi}{2}}$ in the GMSK case. The Synchronization unit 110 detects the modulation type and provides the Derotation unit 120 with the correct rotation factor, i.e., $\theta = \frac{\pi}{8}$ in the 8-PSK case and $\theta = \frac{\pi}{2}$ in the GMSK case. The rotated second portion of the received signal, $\bar{y}_n = e^{-j\theta n} y_n$ together with the synchronization position and information representing the detected modulation type are then fed to a Channel Estimator 130 which estimates the channel based on the training sequence, the detected modulation type, and the derotated received signal. The estimated channel filter taps, $\hat{h}_i, i=0, \dots, L$ are then fed to an Equalizer 140, together with the derotated signal \bar{y}_n , for estimation of the transmitted signal u .

FIG. 2A illustrates a method for simultaneous synchronization and modulation type detection according to the first embodiment. The method begins at step 200 at which a received signal is stored. At step 210, the first portion of the signal, e.g., the training sequence, is correlated with signals representing various modulation types to detect the modulation type of the received signal, and the start of the training sequence is determined to establish burst synchronization. At step 220, the second portion of the received signal, e.g., the information sequence, is derotated. At step 230, channel

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estimation is performed using information representing the determined modulation type, the derotated signal, and the detected synchronization position. Finally, at step 240, the channel is estimated, and the derotated signals are processed in an Equalizer.

In some communication systems, the same training sequence is used for all M
5 different modulation types. In this case, the offset is the information that differs between the different modulation types. According to a second embodiment, the simultaneous synchronization and modulation type detection apparatus shown in FIG. 1B can be used for this type of system.

In the apparatus shown in FIG. 1B, similar to that shown in FIG. 1A, a received
10 signal is stored in a Buffer 100. The first portion of the received signal, e.g., a training sequence, is output from the Buffer 100 to Derotator units 105 that derotate the first portion according to the different offsets for respective modulation types. As an example, assume that $M = 2$ and the two modulation types that are used are either $\pi/8$ offset 8-PSK, so that the transmitted signal u_i is given by Equation 5 or GMSK, i.e., (the linear
15 approximation) in which case the transmitted signal u_i is given by Equation 7. Then, the received signal y_i is de-rotated by $e^{-j\frac{\pi}{8}}$ in Derot₁ 105 and by $e^{-j\frac{\pi}{2}}$ in Derot₂ 105. The derotated outputs $\bar{y}_1, \dots, \bar{y}_M$ are then fed to a Synchronization unit 110 which performs a correlation between the training sequence TS of the communication system and each derotated received sequence $\bar{y}_1, \dots, \bar{y}_M$ in order to find which modulation is used and
20 where the training sequence starts within the burst, to establish burst synchronization. Information representing the detected modulation type is then fed to a Derotation unit 120 that rotates the second portion of the received signal, e.g., the information sequence, by an amount appropriate for the detected modulation type. The rotated received sequence, $\bar{y}_n = e^{-j\theta_n} y_n$, where θ is the decided offset (i.e., which determines the modulation type),
25 together with the synchronization position and information representing the detected modulation type are then fed to the Channel Estimator 130 which estimates the channel based on the training sequence, the detected modulation type and the received signal. The estimated channel filter taps, $\hat{h}_i, i=0, \dots, L$ and information representing the detected modulation type are then fed to the Equalizer 140 together with \bar{y}_n , for further processing.

FIG. 2B illustrates a method for simultaneous synchronization and modulation type detection according to a second embodiment. Similar to the method shown in FIG. 2A, the method begins at step 200 at which a received signal is stored. At step 205, the first portion of the received signal, e.g., the training sequence, is derotated in a number of
5 Derotators. At step 212, the derotated versions of the training sequence are correlated with a training sequence TS of the communication system to detect the modulation type of the received signal, and the start of the training sequence is determined to establish burst synchronization. At step 220, the second portion of the received signal, e.g., the information sequence, is derotated. At step 230, channel estimation is performed using
10 information representing the determined modulation type, the derotated signal, and the detected synchronization position. Finally, at step 240, the channel estimate is processed with the derotated signal in an Equalizer.

In the embodiments above, modulation type detection is performed simultaneously with synchronization by correlating, e.g., the training sequence of the
15 received signal with one or more signals representing modulation types used by the communication system to determine the type of modulation used in the received signal. If the received sequence contains too much noise, the modulation type detection may fail.

According to a third embodiment, an apparatus is provided that handles modulation type detection in case the modulation type detection by the Synchronization unit fails. FIG. 1C illustrates an apparatus for synchronization and modulation type
20 detection according to the third embodiment. The system of FIG. 1C is similar to that shown in FIG. 1A, i.e., a received signal is stored in a Buffer 100, and the first portion of the received signal, e.g., a training sequence, is output from the Buffer 100 to the Synchronization unit 115. A correlation between the different training sequences for each
25 of the M possible modulation types used in the particular communication system, TS_1, \dots, TS_m , and the received training sequence is performed in the Synchronization unit 115 to determine where the training sequence starts within the burst, to establish burst synchronization. Since the radio channel is assumed to be of order L, the synchronization

position for each possible modulation type can be computed by maximizing the energy within a window of length L using equations 3 and 4.

The energies for the best synchronization position for each possible modulation type are then compared to each other. Based on the energy distribution between the modulation types, a decision is made whether the modulation type is detected or not. For example, if:

$$Energy^i(k_{opt}^i) \gg Energy^n(k_{opt}^n), \text{ for all } n \neq i, \quad (9)$$

where k_{opt}^i is the best synchronization position for modulation type i , and k_{opt}^n is the best synchronization position for modulation type n , then a decision is made that the modulation type is modulation type i . On the other hand, if:

$$Energy^i(k_{opt}^i) \approx Energy^n(k_{opt}^n), \text{ for some } n \neq i \quad (10)$$

either a predetermined modulation type may be chosen as the modulation type, or the modulation type decision is not made at this point. For example, the most robust modulation type may be chosen as the modulation type, based on the assumption that the modulation type detection failed due to bad signal quality, implying the most robust modulation is probably used. For example, if GMSK and 8-PSK are the two possible modulation types, GMSK may be chosen as the modulation type since GMSK is quite insensitive to noise and thus more robust than 8-PSK. Hence, after this stage, either the modulation type is detected, or there are $1 < v \leq M$ modulation types left to choose between, where v represents a number of possible modulation types between 1 and the total number of possible modulation types M .

Information about whether the modulation type has been decided is then fed to a Derotator unit 125 that derotates the received samples, either based on the detected modulation type (indicated by a solid line) or according to all v modulation types that are still candidates (indicated by solid and dashed lines). The rotation is performed in order to compensate for offsets introduced in the transmitter, as described above. The rotated second portions of the received signal, $\bar{y}_n^1, \dots, \bar{y}_n^v$, together with the synchronization

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position, the training sequences, $TS_1 \dots TS_m$, and information representing whether the modulation type is detected or not, are then fed to a Channel Estimator 135 which estimates the channel based on the training sequences, information regarding the modulation type, and the derotated received signal portions. The Channel Estimator 135
 5 can be of least-Square type. If modulation type detection has been done in the Synchronization unit 115, the estimated channel filter taps, \hat{h}_i , $i=0, \dots, L$ are then fed to an Equalizer 145, together with the derotated signal \bar{y}_n , for further processing.

If no modulation detection has been done in the Synchronization unit 115, the Channel Estimator 135 estimates v channel estimates, one for each of the possible v
 10 modulation types. A new detection procedure based on some quality measures, such as for instance the estimated signal to noise ratio (SNR), for each of the v modulation types, obtained from the LS-estimate, may be performed in the Channel Estimator 135. The SNR for the modulation type may be defined as follows:

$$15 \quad SNR_i = \frac{\sum_{k=0}^L |\hat{h}_k^i|^2}{\sigma_i^2} \quad (11)$$

where \hat{h}_k^i , $k=0, \dots, L$ are the estimated channel filter taps for modulation type i , and σ_i^2 is the estimated noise power when assuming modulation type i . For instance, if:

$$20 \quad SNR_i \gg SNR_n, \text{ for all } n \neq i \quad (12)$$

then modulation type i is detected. The estimated channel filter taps \hat{h}_i , $i = 0, \dots, L$ and the detected modulation type are then fed to the Equalizer together with \bar{y}_n for further processing.

If no modulation type detection is performed in the Channel Estimator 135,
 25 because w candidates, where $1 < w \leq v$, have approximately the same SNR, the channel filter taps for all these w modulation types $\{\hat{h}_i^1\}_{i=(0,L)} \dots \{\hat{h}_i^w\}_{i=(0,L)}$ are fed to the Equalizer 145. Then, w equalizations are performed in the Equalizer 145, and the results for each of the w modulation types together with the information regarding whether the

modulation type is detected or not are fed to a Decision unit 150. In the Decision unit 150, a decision can be made which of the w modulation types the received signal is modulated with based on metrics from the Equalizer 145, the computation of metrics being known in the art.

5 FIG. 2C illustrates a method for synchronization and modulation type detection according to the third embodiment. The method begins at step 200 at which a received signal is stored. At step 215, an attempt is made to correlate a portion of the signal, e.g., the training sequence, with signals representing various modulation types to detect the modulation type of the received signal, and the start of the training sequence is
10 determined to establish burst synchronization. A determination is made at step 218 whether the modulation type is detected or not. If the type of modulation is detected, at step 220, the second portion of the received signal, e.g., the information sequence, is derotated. At step 230, channel estimation is performed using information representing the determined modulation type, the derotated signal, and the detected synchronization
15 position. At step 240, the derotated signals are processed in an Equalizer.

 If, at step 218, it is determined that the modulation type is not detected, the method proceeds to step 225 at which the second portion of the received signal is derotated according to all candidate modulation types. Next, at step 235, channel estimation is performed using the training sequences and the rotated second portions. At
20 step 237, modulation type detection is again attempted, based on a comparison of signal qualities. At step 239, a determination is made whether the modulation type is detected. If so, equalization is performed at step 245. Otherwise, equalization is performed for all the candidate channel estimates at step 247, and the modulation type is finally decided at step 250.

25 According to a fourth embodiment, the synchronization and modulation type detection apparatus shown in FIG. 1D can be used for a system in which the same training sequence is used for all M different modulation formats.

 In the apparatus shown in FIG. 1D, similar to that shown in FIG. 1B, a received signal is stored in a Buffer 100. The first portion of the received signal, e.g., a training

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sequence, is output from the Buffer 100 to Derotator units 105 that derotate the first portion according to the different offsets for respective modulation types. The received signal y_1 is de-rotated by $e^{-j\frac{\pi}{8}}$ in Derot₁ 105 and by $e^{-j\frac{\pi}{2}}$ in Derot₂ 105. The derotated outputs $\bar{y}_1, \dots, \bar{y}_M$ are then fed to a Synchronization unit 115 which performs a correlation between the training sequence TS of the communication system and each derotated received sequence $\bar{y}_1, \dots, \bar{y}_M$ in order to find where the training sequence starts within the burst, to establish burst synchronization. The channel estimation, further derotation, equalization, and decision of modulation type detection are then performed as described above with reference to FIGS. 1B and 1C.

FIG. 2D illustrates a method for synchronization and modulation type detection according to a second embodiment. Similar to the method shown in FIG. 2B, the method begins at step 200 at which a received signal is stored. At step 205, the first portion of the received signal, e.g., the training sequence, is derotated in a number of Derotators. At step 217, an attempt is made to detect the modulation type by correlating the derotated versions of the training sequence, and the start of the training sequence is determined to establish burst synchronization. At step 218, a determination is made whether the modulation type was detected. If so, at step 220, the second portion of the received signal, e.g., the information sequence, is derotated. At step 230, channel estimation is performed using information representing the determined modulation type, the derotated signal, and the detected synchronization position. At step 240, the channel estimate is processed with the derotated signal in an Equalizer.

If, at step 218, it is determined that the modulation type is not detected, the process proceeds to step 225 at which the second portions of the received signal are derotated. Next, at step 235, channel estimation is performed using the training sequence and the rotated second portions. At step 237, modulation type detection is again attempted, based on a comparison of signal qualities. At step 239, a determination is made whether the modulation type is detected. If so, equalization is performed at step 245. Otherwise, equalization is performed for all the candidate channel estimates at step 247, and the modulation type is finally decided at step 250.

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It will be appreciated that the order of steps described in the embodiments above is given by way of example only, and the order can be changed as desired. For example, the second portion of the received signal can be derotated at any convenient point before equalization.

5 This invention relates to all areas where synchronization and detection are used in digital communication. The invention proposes a fast and simple method for burst synchronization and modulation type detection. The invention is particularly suitable for mobile and base stations in cellular communication systems, but its applications are not limited to them.

10 It will be appreciated by those of ordinary skill in the art that this invention can be embodied in other specific forms without departing from its essential character. The embodiments described above should therefore be considered in all respects to be illustrative and not restrictive.

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WHAT IS CLAIMED IS:

1. In a communication system including a transmitter and a receiver, an apparatus for synchronizing the receiver with the transmitter and detecting a modulation type in a signal transmitted by the transmitter and received by the receiver, the apparatus comprising:
5 a detector for detecting the type of modulation being used in the received signal by correlating a first portion of the received signal with one or more signals representing modulation types used by the communication system to; and
10 a synchronization unit for synchronizing the receiver with the transmitter.
2. The apparatus of claim 1, wherein the detector correlates the first portion of the received signal with each of one or more different signals representing various modulation types used in the communication system to detect the type of modulation
15 used.
3. The apparatus of claim 1, further comprising a derotator for derotating the received signal by different amounts to produce a plurality of derotated signals, wherein the detector correlates the signal representing a modulation used by the communication
20 system with each derotated signal in order to detect the type of modulation used.
4. The apparatus of claim 1, further comprising a channel estimator for estimating a channel of the received signal based on the detected modulation type.
- 25 5. The apparatus of claim 1, further comprising a derotator for derotating a second portion of the received signal to compensate for offsets introduced by the transmitter.

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6. The apparatus of claim 4, further comprising an equalizer for equalizing the channel estimate and the second portion of the received signal.

7. The apparatus of claim 1, wherein modulation type detection and
5 synchronization are performed simultaneously.

8. The apparatus of claim 1, wherein the first portion of the received signal is a training sequence, and a second portion of the received signal is an information sequence.

10

9. The apparatus of claim 1, further comprising a decision unit, wherein if the type of modulation is not detected by the detector, either a predetermined modulation type is determined to be the modulation type used or a decision of the modulation type is made by the decision unit.

15

10. The apparatus of claim 9, wherein the decision unit decides the modulation type based on a comparison of signal qualities.

11. The apparatus of claim 9, further comprising an equalizer, wherein the
20 decision unit decides the modulation type based on equalization results.

12. In a communication system including a transmitter and a receiver, a method for synchronizing the receiver with the transmitter and detecting a modulation type in a transmitted signal received by the receiver, the method comprising the steps of:
25 detecting the type of modulation being used in the received signal by correlating a first portion of the received signal with one or more signals representing the type of modulation used by the communication system; and
synchronizing the receiver with the transmitter.

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13. The method of claim 12, wherein the step of detecting includes correlating the first portion with each of one or more different signal representing various modulation types used in the communication system to detect the type of modulation used.

5

14. The method of claim 12, further comprising a step of derotating the first portion by different amounts to produce a plurality of derotated signals, wherein the step of detecting includes correlating the signal representing the modulation used by the communication system with each derotated signal in order to determine the type of modulation used.

10

15. The method of claim 12, further comprising estimating a channel of the received signal based on the detected modulation type.

15

16. The method of claim 12, further comprising derotating a second portion of the received signal to compensate for offsets introduced by the transmitter.

17. The method of claim 15, further comprising equalizing the channel estimate and the second portion of the received signal.

20

18. The method of claim 12, wherein the steps of detecting and synchronizing are performed simultaneously.

19. The method of claim 12, wherein the first portion of the received signal is a training sequence, and a second portion of the received signal is an information sequence.

25

20. The method of claim 12, wherein if the type of modulation is not

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detected by the detecting step, either a predetermined modulation type is determined to be the modulation type used or the method includes a further step of deciding the modulation type.

5 21. The method of claim 20, wherein the deciding step decides the modulation type based on a comparison of signal qualities.

 22. The method of claim 20, further comprising a step of equalizing, wherein the deciding step decides the modulation types based on equalization results.

10

FIG. 1A

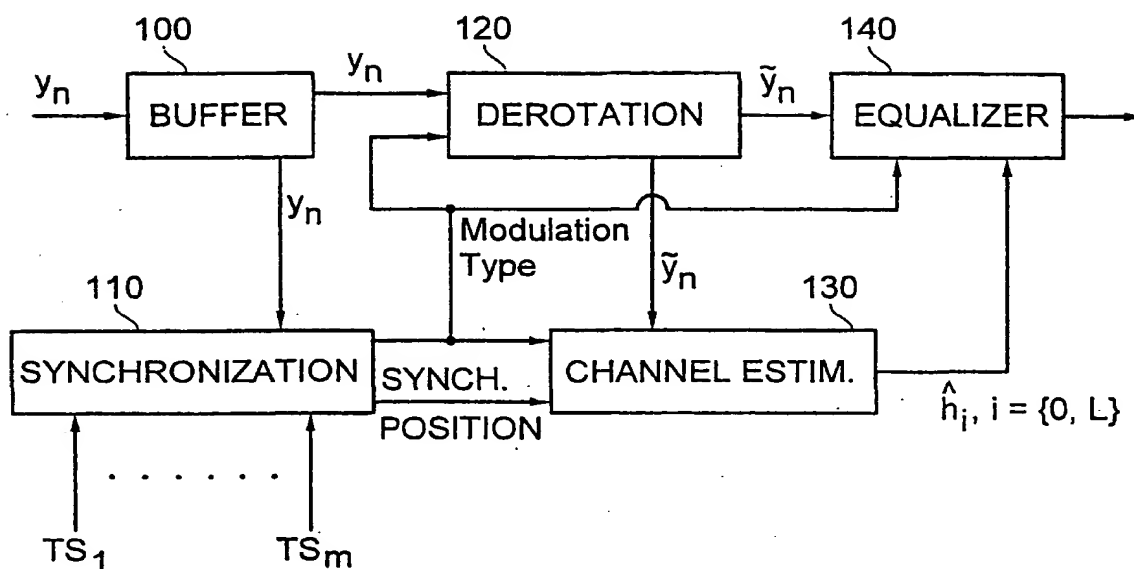


FIG. 1B

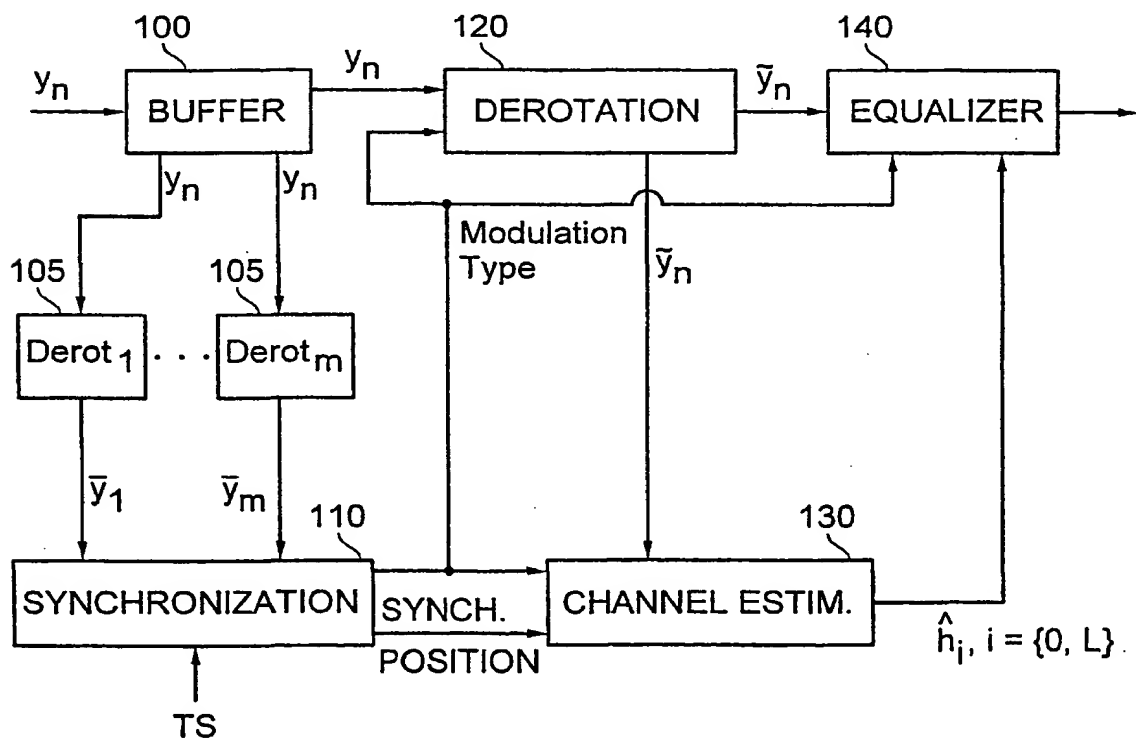


FIG. 1C

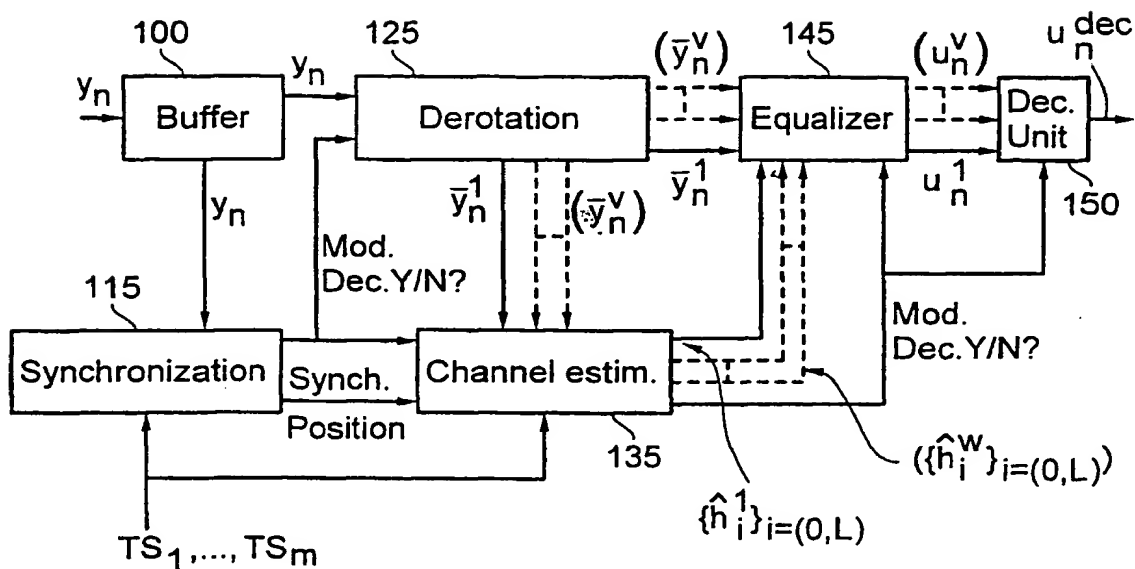
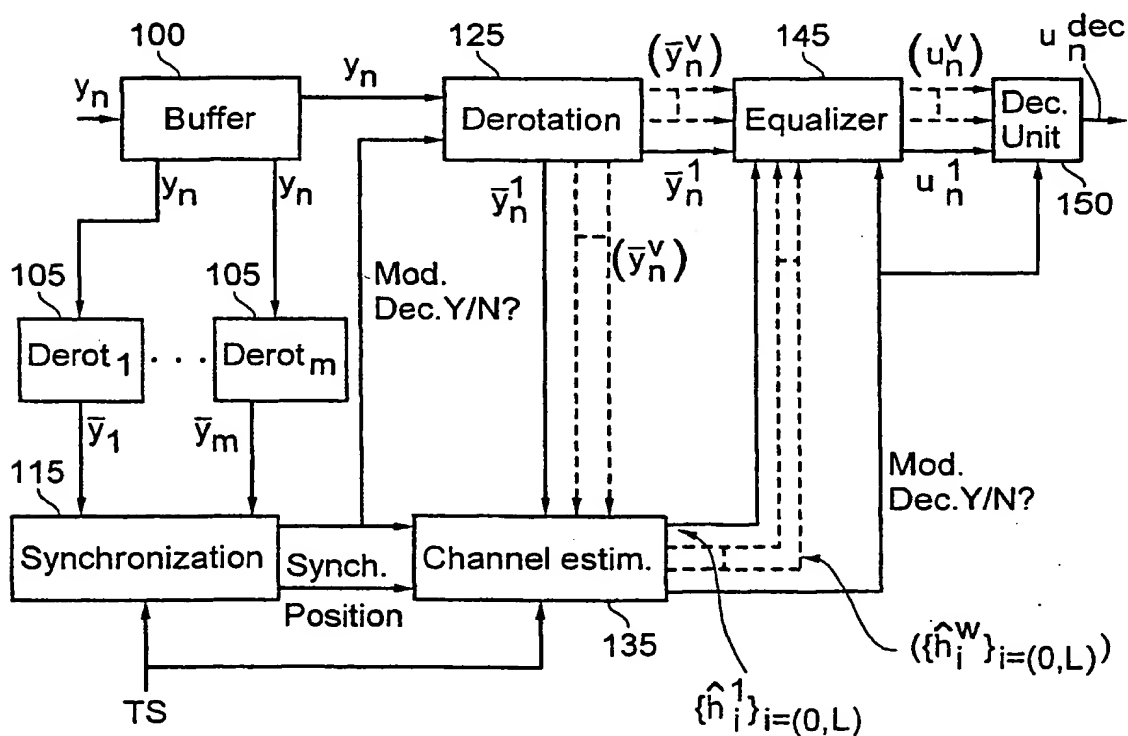


FIG. 1D



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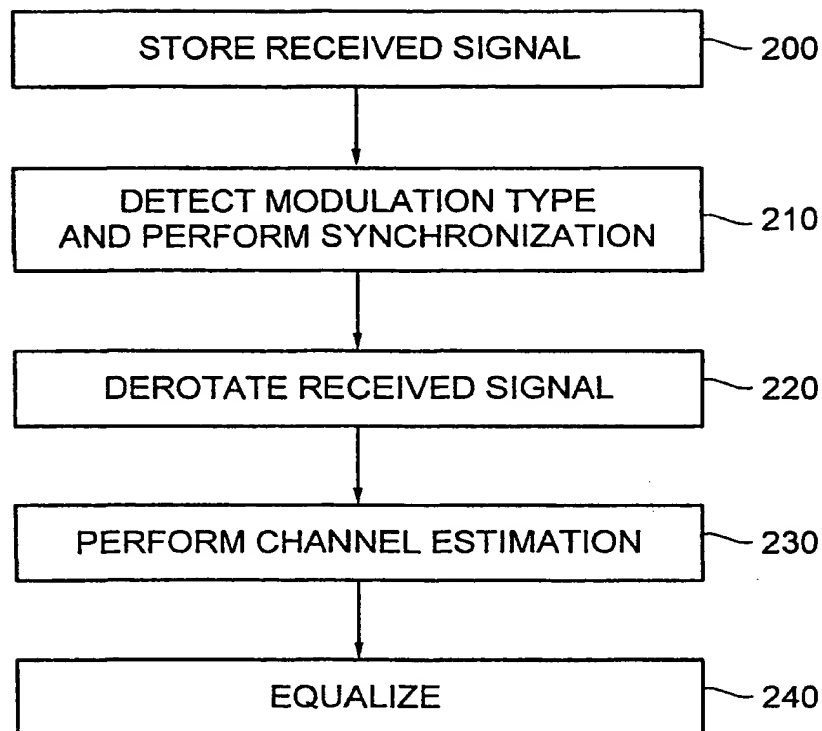


FIG. 2A

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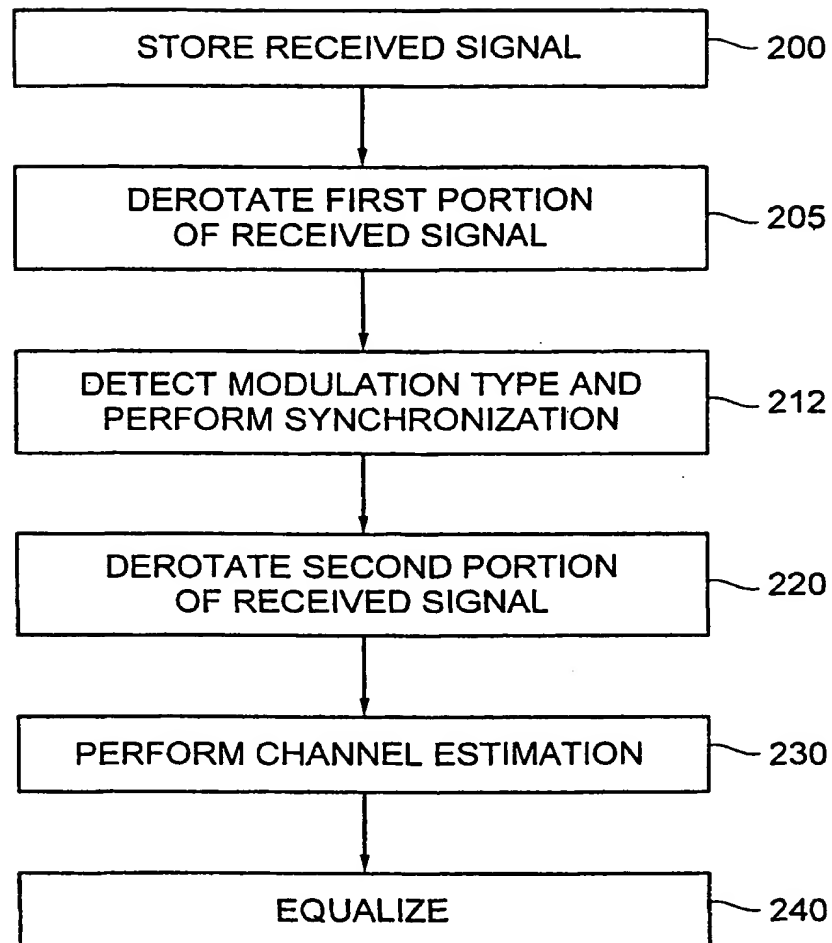


FIG. 2B

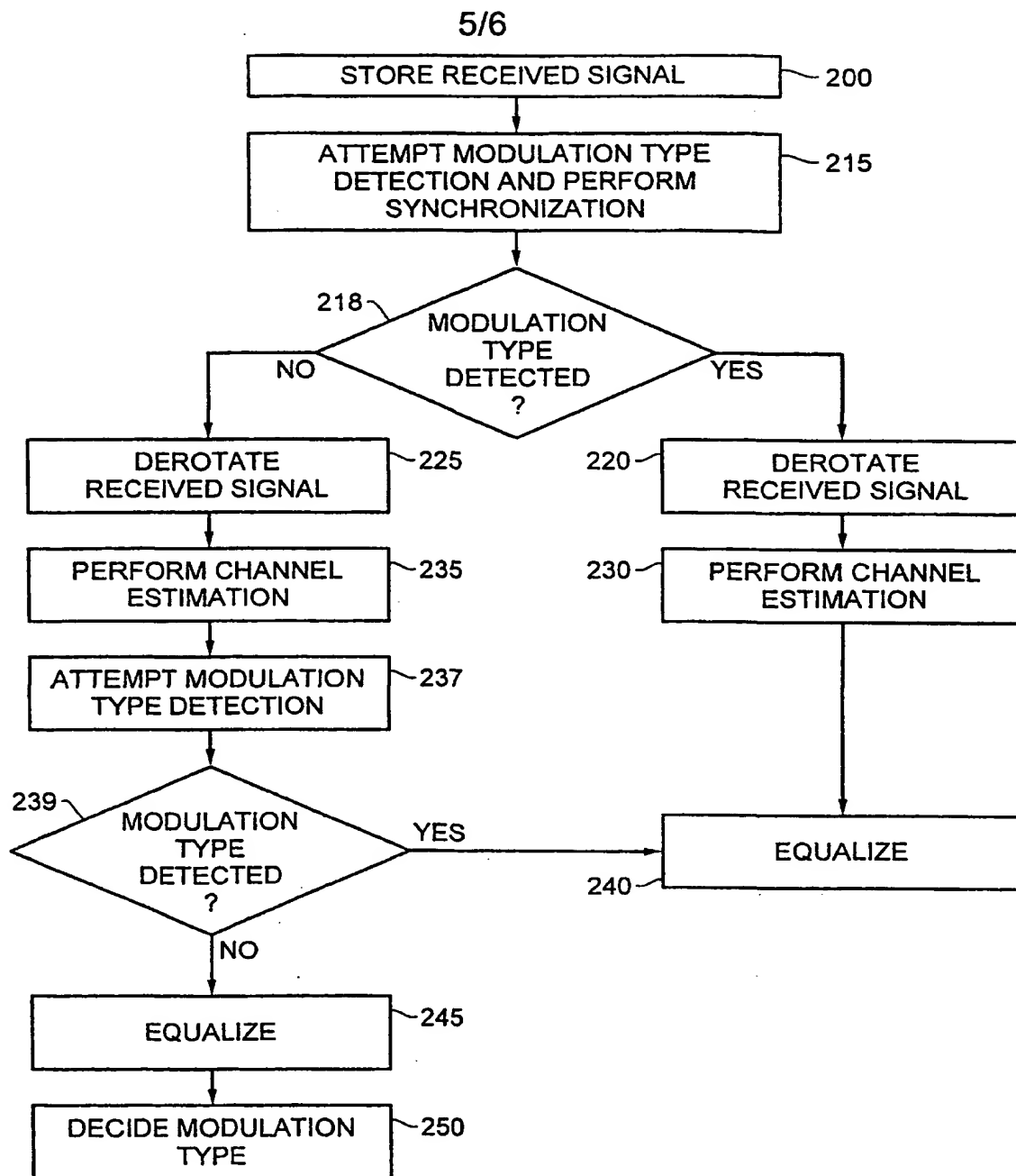


FIG. 2C

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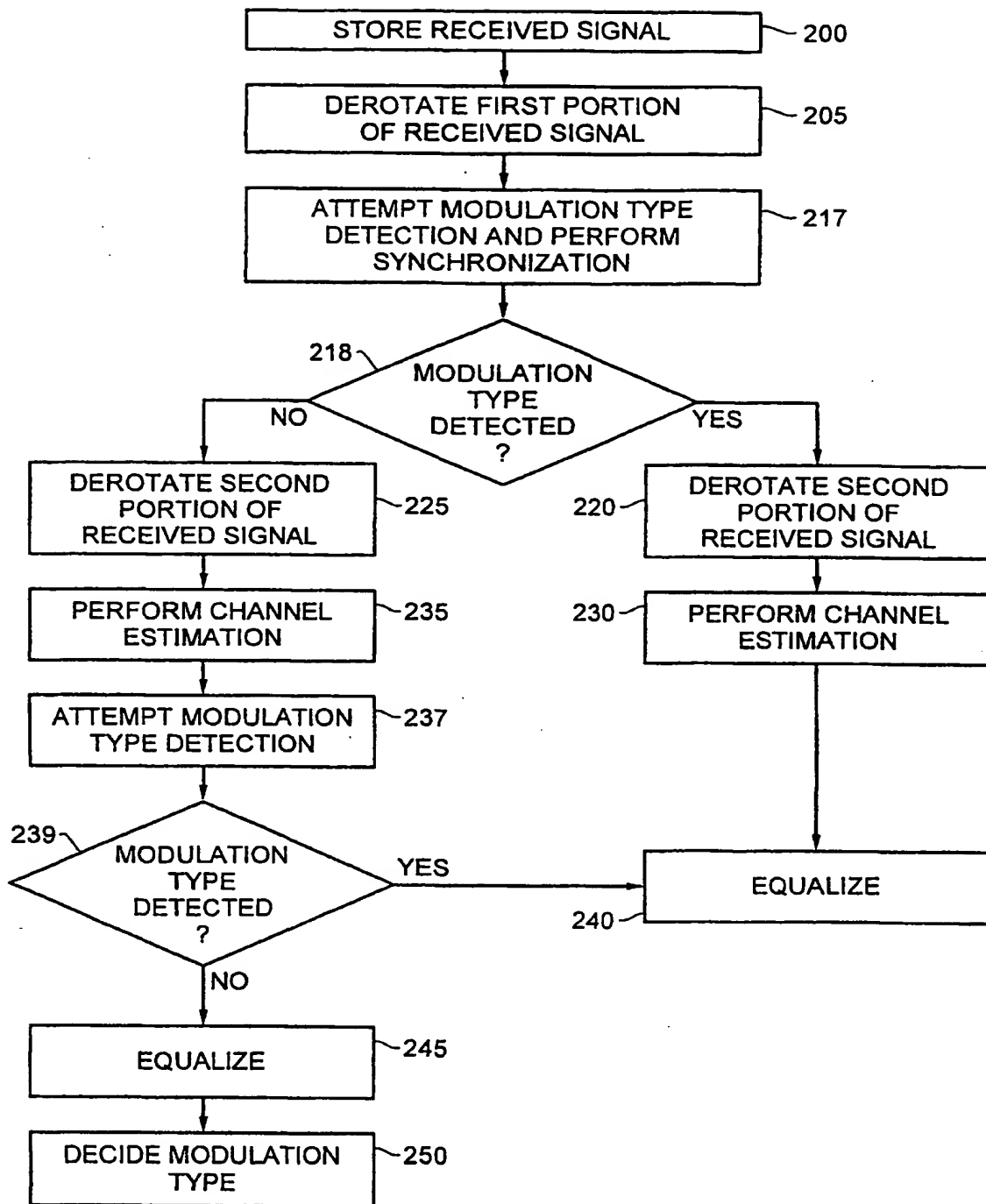


FIG. 2D

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/05982

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L27/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, WPI Data, EPO-Internal, INSPEC, COMPENDEX

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
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Date of the actual completion of the international search

20 October 2000

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/05982

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